

Water: Neglected, unappreciated and under researched

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Abstract

Water, an essential nutrient, is often ignored in reports of dietary surveys and nutrition.

Although it is ubiquitous in foods and beverages, the attention is often focused on the minerals or calorific values of the fluids imbibed rather than the water per se. Water is often taken for granted by many in Western countries due to its abundant availability through water systems.

In developing countries, however, water and sanitation raise significant problems. This review overviews (i) the global perspective of the potable water supply, (ii) human rights and water, (iii) dietary guidelines and sources of water, and (iv) the physiology of water balance. Gaps in knowledge and understanding around hydration and water requirements are also discussed.

Nutritionists are urged to look at the bigger picture of the global water supply and to use good judgement and common sense when advising on water requirements.

Key words: Water, nutrient, global, dietary guidelines, hydration

Preamble

Water is essential for all forms of life and is relatively ubiquitous. In human nutrition, water is often ignored in research reporting dietary intake and food consumption patterns. Nutrition journal reviews in 1999 (ref. 1), 2009 (ref. 2) and 2010 (ref. 3) have highlighted water as an essential, and often ignored nutrient, while others have addressed the importance of water and hydration for the individual¹⁻⁴. Discussion of individual requirements for water and recommended dietary intake (RDI) guidelines has received some attention⁵⁻⁸ but there is not a clear consensus in public health or clinical medicine of what the message should be and how it should be delivered. This may be due to the limited amount of objective research that has been undertaken concerning actual water intake and turnover among populations who (i) live in different environments, (ii) have varied levels of activity and (iii) are at different life stages.

The ability to continue to support food production on this planet is dependent on water, yet rapid population growth and economic development combined with global climate change are impacting on the availability of potable water⁹. Of particular concern is the adequacy of safe drinking water for populations. Disasters and emergencies, add to the challenge where often the priority for short term survival is potable water for drinking and then cooking; cleaning becomes a secondary consideration.

The complexity of the challenge of understanding water as a nutrient and source of life on this planet may be portrayed as clusters of factors that impinge on an individual's water balance and turnover. A very simple schematic (**Figure 1**) modelled on the Foresight Obesity System Maps¹⁰ depicts some major effectors of potable water availability and water balance.

Global perspective

The millennium development goals (MDGs) promulgated in 2000 included a goal to ensure environmental sustainability¹¹. In the year 2000, more than one billion people were without sustainable access to safe drinking water and basic sanitation and the goal set for 2015 was to halve this number. Progress towards MDGs has been uneven and most goals including water and basic sanitation will not be met^{12, 13}.

On 28 July 2010, through Resolution 64/292 the United Nations General Assembly explicitly recognised the human right to water and sanitation. This resolution was based on the understanding that clean drinking water and sanitation are essential to the realisation of all human rights and living a life in human dignity. The right to water now stands alongside the right to food: first recognised by the United Nations in 1945. Similar to food security, water security means that water is sufficient, safe, acceptable, physically accessible and affordable.

The right to water and access to water are considered crucial to well-being and quality of life. Yet the link between the right and access for an individual is dependent on governance and operationalization¹⁴, soft-path strategies that require the participation of local communities and alternative technologies¹². As the number of people living in water-stressed regions continues to increase and effects of climate change and population growth continue to impact¹⁵ innovative and adaptive solutions become more imperative.

Individual perspective

The proportion of body mass that is water can range from 30 to 70%, association with a body fat percentage of 60% and 5% respectively. Under normal conditions the hydration of the fat free mass (FFM) varies by only a few percentage points¹⁶⁻¹⁸ with the average of 73.2% water.

Water as a molecule has unique chemical and physical properties; that are related to specific functions in the human body¹⁹. Its distribution is tightly regulated²⁰ and any changes in water balance, including shifts within the body, stimulate the response of exquisitely sensitive physiological mechanisms to maintain tight control of osmolarity and sodium balance. Water is continually lost from the body through respiration, urine formation, insensible loss, sweat and faeces. It is gained from fluids including water and food and also from catabolic processes where water is released.

Objective measures of water balance

Direct measurements of total amount of water gained and lost are not possible and determinations that rely on interviews or recall of food intake are not reliable²¹. Clinical fluid management assessment and practice are predicated on observations²² that are not supported by a strong evidence base. One objective way to measure water turnover is to administer an accurately measured dose of deuterium labelled water. Within 3 to 5 hours, the isotopically labelled water equilibrates with body water and total body water may be determined²³. The labelled water is lost from the body through all routes and is diluted by the water gained. The time course of this loss provides a measure of water turnover and it is assumed that water balance is maintained i.e. input = output. Dependent on the dose and biological half-life of the label, the usual time of measurement is over 7 to 14 days. The advantage is that the individuals are free living and the only requirement after dosing is that timed samples of urine or other

body fluid are collected. The elimination rate may be determined by a two point calculation where only a baseline, a sample after the dose has equilibrated and another sample from the finish of the period are required²⁴. The multipoint method of calculation requires more samples, preferably at regular intervals and this may give better combined precision and accuracy²⁵, with the coefficient of variation 5.4% compared with 3.6% for the two point determination. Either way the accuracy of water turnover measured by deuterium dilution far exceeds other methods of assessment of water turnover but is not suitable for measurements of rapidly changing water balance.

Using the deuterium dilution approach others have found high inter individual variability in the water turnover of adults²⁶, even though only small age differences in these populations were seen. One water balance study²⁷ found no difference in water turnover between subjects aged 23-46y and 63-81y. Other studies have assessed water turnover in the middle-aged and elderly^{26, 28, 29} but very few have examined younger age groups. Only one³⁰ has focused on young adults outside of specialized sports activities, two have looked at child water turnover^{30, 31} and one has examined water turnover of overweight adolescents³². These and other studies have reported wide inter individual variation which adds to the difficulty of accurate public health messages around how much fluid an individual requires in a day.

Public health messages should be clear, achievable and based on evidence. For example for survival the World Health Organisation recommends that each individual needs between 2.5 to 3 litres each day in drink and food but comments that this depends on climate and individual physiology³³. This simple advice is relevant to a wide range of emergency situations. In order to provide context to advice for individual water requirements the data from the study of water turnover in children and young adults in temperate New Zealand³⁰ has been examined further.

When water turnover was regressed against body mass (Figure 2) the regression equation for predicting water turnover ($\text{L}\cdot\text{day}^{-1}$) was: $0.949 + 0.024 \text{ body mass in kg}$ ($\text{SEE}=0.71$ and $r^2=0.52$). In rounded terms one litre plus 250 mL for every 10kg of body weight. Furthermore the Rush study³⁰ showed that the variation in water turnover when indexed to total energy expenditure, was higher in women and men than in girls and boys respectively. The variation is right skewed (**Figure 2**); demonstrating that there is a tendency for mean consumption to be greater than the median. While not measured social imbibing and habitual sipping rather than drinking for thirst may explain the higher water turnover in these adults.

Guidelines not tramlines

Three underlying principles govern guidelines around fluid intake. The first is that fluid intake does not have to be water because requirements may be met by other sources of fluid including tea, coffee, milk and food. Secondly, beverages with no or few calories should take precedence over the consumption of beverages with more calories³⁴. Thirdly, because of variations in physical activity levels, climate, air conditioning and body size and surface area there is a wide variation in actual fluid requirements. Government guidelines for adequate fluid intake are based on observations. The often quoted “drink at least eight glasses of water a day” has no underpinning scientific evidence^{35, 36} and does not account for other sources of fluid. While it is recognised that water intake “ahead of thirst” may cause exercise associated hyponatraemia³⁷, this is considered a rare occurrence in the general population and there is not enough evidence to set a recommended dietary intake or upper limit for fluid intake. Furthermore there is no clear evidence for lack of benefit of increased water ingestion^{38, 39} and limited reports of positive effects of water consumption on cognition, physical performance, child health, primary and public health⁴⁰. This limited evidence may be used by Big Food multinationals to help market health⁴¹ and in particular water and the “importance of hydration”⁴⁰.

The evidence base to support claims of widespread dehydration and the need to drink ahead of thirst does not exist. Yet, the need to be “optimally hydrated” still receives a lot of attention. Reports of dehydration have been associated with cognitive decline⁴², and the advocacy particularly by the sports drink industry to drink ahead of thirst are based on limited evidence that this will help to avoid heat stroke, dehydration and improve health and performance^{37, 43}. Furthermore there is a danger that the advice to drink ahead of thirst may be associated with hyponatraemia⁴⁴, independent of whether it is water or a sports drink.

In temperate climates and for moderate energy expenditure requirements for fluid intake (including the water in food) recommendations are 1 mL/kcal⁴⁵. Popkin et al. applied this “rule” to NHANES 2005-2006 data and identified that children aged less than 14 years were consuming around 75% of the water recommended. Evidence that this translates into dehydration and puts children at risk is lacking, as are biomarkers for hydration status.

Market forces versus public health messages.

In more affluent societies there is a public perception that although bottled water costs more it tastes better and is safer than tap water⁴⁶. Evidence for a growing preference is provided by increasing market share for bottled water³⁸. The annual sales of bottled fluid water has burgeoned in 76 countries from 175000 million litres in 2005 to 237000 million litres in 2010 (ref.50). In 2010 the two countries accounting for sales of 30000 million litres each (25% of total) were China and the United States. For the United States this approximates to 96 litres for each person each year. While this may be seen as a move away from caloric beverages it may also be seen as successful marketing of the importance of hydration.

Conclusion

Water is absolutely necessary and fundamental to life and like food access to adequate water is a human right. Essential to the health of ecosystems, food supplies and individuals water is both an under-researched nutrient and over-exploited resource in the world. From a global perspective and current practice water insecurity will increase and impact on ecological and human health.

The information around individual water balance is lacking and guidelines and public health messages around water are not clear. More evidence is required including how to translate accumulating knowledge into safe practice and recommendations.

More than 2000 years ago Hippocrates c(460-377BC) said “If we could give every individual the right amount of nourishment and exercise, not too little and not too much, we would have found the safest way to health”. Future research should not only examine basic physiology and water requirements but also take into account the wider impacts of global climate, change, local environments, water availability and potability, water distribution systems and commercial concerns.

CONFLICT OF INTEREST

The author declares that she does not have any competing financial interests in relation to the work described.

References

1. Holdsworth JE. The importance of human hydration: Perceptions among healthcare professionals across Europe. *Nutr Bull* 2012; **37**: 16-24.

2. Karowicz-Bilińska A. Water and its importance for female body. *Woda i jej znaczenie dla organizmu kobiety* 2011; **82**: 455-459.
3. Popkin BM, D'Anci KE, Rosenberg IH. Water, hydration, and health. *Nutr Rev* 2010; **68**: 439-458.
4. Jéquier E, Constant F. Why do we have to drink water? For maintaining the water balance. *Pourquoi faut-il boire de l'eau? Pour maintenir la balance hydrique* 2009; **44**: 190-197.
5. European Food Safety Authority (EFSA) Panel on Dietetic Products NaA. Scientific Opinion on Dietary Reference Values for water. *EFSA Journal* 2010; **8**: 1459.
6. Sawka MN, Cheuvront SN, Carter Iii R, Jéquier E, Manz F, Dal Canton A *et al.* Human water needs. *Nutr Rev* 2005; **63**: S30-S39.
7. Valtin H, Gorman SA. "Drink at least eight glasses of water a day." Really? Is there scientific evidence for "8 × 8"? *AJP - Regul Physiol* 2002; **283**: 993-1004.
8. Manz F, Wentz A, Sichert-Hellert W. The most essential nutrient: Defining the adequate intake of water. *J Pediatr* 2002; **141**: 587-592.
9. Vörösmarty CJ, Green P, Salisbury J, Lammers RB. Global water resources: Vulnerability from climate change and population growth. *Science New York, NY* 2000; **289**: 284-288.
10. Vandenbroeck I, Gossens J, Clemens M. Foresight Tackling Obesities: Future Choices—Obesity System Atlas. In: Science GO of (ed). *UK Government's Foresight Programme*. Government Office for Science: London, 2007.
11. A/RES/55/2. United Nations Millennium Declaration: resolution adopted by the General Assembly, 2000.
12. Gerlak AK, Wilder M. Exploring the Textured Landscape of Water Insecurity and the Human Right to Water. *Environment* 2012; **54**: 4-17.

13. Nations U. Millennium Development Goals:2011 Progress Chart. Statistics Division, Department of Economic and Social Affairs, United Nations, 2011.
14. Anand PB. Right to water and access to water: an assessment. *J Int Dev* 2007; **19**: 511-526.
15. Arnell N. Climate change and global water resources: SRES emissions and socio-economic scenarios. *Global Environ. Change* 2004; **14**: 31-52.
16. Fomon SJ, Haschke F, Ziegler EE, Nelson SE. Body composition of reference children from birth to age 10 years. *Am J Clin Nutr* 1982; **35**: 1169-1175.
17. Lohman TG. Applicability of body composition techniques and constants for children and youths. *Exerc Sport Sci Rev* 1986; **14**: 325-357.
18. Wang Z, Deurenberg P, Wang W, Pietrobelli A, Baumgartner RN, Heymsfield SB. Hydration of fat-free body mass: review and critique of a classic body-composition constant. *Am J Clin Nutr* 1999; **69**: 833-841.
19. Jequier E, Constant F. Water as an essential nutrient: the physiological basis of hydration. *Eur J Clin Nutr* 2010; **64**: 115-123.
20. Kleiner SM. Water: an essential but overlooked nutrient. *J Am Diet Assoc* 1999; **99**: 200-206.
21. Johansson G, Wikman A, Ahren AM, Hallmans G, Johansson I. Underreporting of energy intake in repeated 24-hour recalls related to gender, age, weight status, day of interview, educational level, reported food intake, smoking habits and area of living. *Public Health Nutr* 2001; **4**: 919-927.
22. Singer M. Management of fluid balance: a European perspective. *Curr Opin Anaesthesiol* 2012; **25**: 96-101.
23. Schoeller DA, van Santen E. Measurement of energy expenditure in humans by doubly labeled water method. *J Appl Physiol* 1982; **53**: 955-959.

24. Schoeller DA, Taylor PB. Precision of the doubly labelled water method using the two-point calculation. *Hum Nutr Clin Nutr* 1987; **41C**: 215-223.
25. Cole TJ, Coward WA. Precision and accuracy of doubly labeled water energy expenditure by multipoint and two-point methods. *Am J Physiol* 1992; **263**: E965-973.
26. Raman A, Schoeller DA, Subar AF, Troiano RP, Schatzkin A, Harris T *et al*. Water turnover in 458 American adults 40-79 yr of age. *Am J Physiol Renal Physiol* 2004; **286**: F394-401.
27. Bossingham MJ, Carnell NS, Campbell WW. Water balance, hydration status, and fat-free mass hydration in younger and older adults. *Am J Clin Nutr* 2005; **81**: 1342-1350.
28. Leiper JB, Carnie A, Maughan RJ. Water turnover rates in sedentary and exercising middle aged men. *Br J Sports Med* 1996; **30**: 24-26.
29. Leiper JB, Seonaid Primrose C, Primrose WR, Phillimore J, Maughan RJ. A comparison of water turnover in older people in community and institutional settings. *J Nutr Health Aging* 2005; **9**: 189-193.
30. Rush EC, Chhichhia P, Kilding AE, Plank LD. Water turnover in children and young adults. *Eur J Appl Physiol* 2010; **110**: 1209-1214.
31. Fusch C, Hungerland E, Scharrer B, Moeller H. Water turnover of healthy children measured by deuterated water elimination. *Eur J Pediatr* 1993; **152**: 110-114.
32. O'Connell BN, Weinheimer EM, Martin BR, Weaver CM, Campbell WW. Water turnover assessment in overweight adolescents. *Obesity (Silver Spring)* 2011; **19**: 292-297.
33. Reed B, Reed R. How much water is needed in emergencies. In: Reed R (ed). *WHO technical notes on drinking-water, sanitation and hygiene in emergencies*. World Health Organisation, Geneva, 2011.

34. Popkin BM, Armstrong LE, Bray GM, Caballero B, Frei B, Willett WC. A new proposed guidance system for beverage consumption in the United States. *Am J Clin Nutr* 2006; **83**: 529-542.
35. Benelam B, Wyness L. Hydration and health: A review. *Nutr Bull* 2010; **35**: 3-25.
36. Valtin H. "Drink at least eight glasses of water a day." Really? Is there scientific evidence for "8 x 8"? *Am J Physiol Regul Integr Comp Physiol* 2002; **283**: R993-1004.
37. Noakes TD. Is drinking to thirst optimum? *Ann Nutr Metab* 2010; **57 Suppl 2**: 9-17.
38. McCartney M. Health marketing: Waterlogged? *BMJ* 2011; **343**.
39. Negoianu D, Goldfarb S. Just Add Water. *J Am Soc Nephrol* 2008.
40. Buyckx ME. Hydration and health promotion: a brief introduction. *J Am Coll Nutr* 2007; **26**: 533S-534S.
41. The PLoS Medicine Editors. PLoS Medicine series on Big Food: the food industry is ripe for scrutiny. *PLoS Med* 2012; **9**: e1001246.
42. Benton D. Dehydration influences mood and cognition: a plausible hypothesis? *Nutrients* 2011; **3**: 555-573.
43. Cohen. The truth about sports drinks. *BMJ* 2012;345:e4737 doi: 101136/bmj.e4737 (Published 18 July 2012) 2012.
44. Almond CS, Shin AY, Fortescue EB, Mannix RC, Wypij D, Binstadt BA *et al*. Hyponatremia among runners in the Boston Marathon. *N Engl J Med* 2005; **352**: 1550-1556.
45. Food and Nutrition Board. Recommended Dietary Allowances. National Academy Press: Washington, 1989.
46. Doria MF. Bottled water versus tap water: understanding consumers' preferences. *J Water Health* 2006; **4**: 271-276.

Legends for figures

Figure 1 Schematic of interactions among factors that affect global and individual water homeostasis.

Figure 2 Relationship between body mass and water turnover across a wide range



